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IGY BULLETIN

A monthly survey by the U. S. National Committee for the International Geophysical Year. Established by and part of the National Academy of Sciences, the Committee is responsible for the U. S. International Geophysical Year program in which several hundred American scientists are participating and many public and private institutions are cooperating.

Volunteer Participation in the IGY Earth Satellite Program

The launching of the first artificial earth satellite on October 4, 1957, illustrated the importance of volunteer programs throughout the world for "acquiring" and tracking earth satellites and for the reception of telemetered data transmitted from them.

There are four distinct ways in which volunteers can contribute to the IGY Earth Satellite Program. First, they may join together in visual observation teams using relatively simple optical instruments. Second, they may establish radio tracking stations in conjunction with amateur radio clubs, universities or other scientific groups. Third, telemetry signals—scientific data transmitted by radio—from instrumented satellites may be recorded and forwarded to IGY centers for analysis. Fourth, volunteers may photograph satellite passages against the background starfield by means of high quality cameras and special techniques.

Visual Observation

The volunteer teams for visual observation are organized in a special program, called Moonwatch, established over a year ago under the auspices of the Smithsonian Astrophysical Observatory. To date, over 00 volunteer visual observation stations have been established within the US. Another 62 stations have either been established or are in the process of being established throughout the world in locations other than within the US or the USSR. Still another 66 stations are reported to have been established within the USSR as part of the Russian equivalent of Moonwatch.

The methods and instruments employed for visual observation of both US and USSR satellites are similar. Visual data are important for acquiring the satellites and for obtaining air density data in the final phase of each satellite's life. During this final period the satellite's batteries will probably have exhausted their power and the orbit parameters may be changing too rapidly to allow observation by precision tracking cameras. The wide coverage made possible by the visual program's many stations will therefore be of great importance. The observing methods of the Moonwatch program are detailed elsewhere in this issue of the *Bulletin*.

Radio Tracking and Telemetry Recording

The second and third types of volunteer participation, radio tracking and telemetry recording, are being handled through a recently organized program called Moonbeam.

Moonbeam preparations were made on the assumption that satellite transmitters would all utilize the 108 megacycle frequency for the transmission of tracking and telemetry signals. However, radio amateurs and scientific groups showed themselves remarkably adept in obtaining data on the first Russian satellites, which operated on 20 and 40 mc.

The primary system for tracking satellites by radio and recording their telemetry signals is the "Picket Fence" of Minitrack stations. However, material assistance will be given by the Moonbeam program, a supporting, secondary network of less elaborate stations operated by volunteer groups of scientists and radio amateurs.

The Moonbeam stations will be able to provide tracking data on the US satellite of sufficient accuracy to be of value for (1) acquisitional purposes, (2) possible resolution of small perturbations in the orbit due to localized gravitational anomalies, (3) supplementary data in case of premature failure of the transmitter or short life of the vehicle, (4) provision of additional data on the influence of the ionosphere upon radio signals.

In addition, the intervals of telemetered scientific data which may be recorded by these volunteer radio stations may prove to be particularly valuable (1) when the recorded interval coincides with a solar flare or other special occurrence, (2) in the event of failure of a data storage element in the satellite, (3) by providing a correlation check of time and position for the primary recording of data from those experiments using satellite-borne tape recorders, (4) for recording the time and circumstances of catastrophic damage to a satellite, should this occur.

Moonbeam will employ two tracking systems. The Mark II Minitrack system has been constructed by the Naval Research Laboratory and tested to demonstrate its suitability for use in radio tracking and telemetry. Another system, the Microlock, developed by the Jet Propulsion Laboratory of the California Institute of Technology for application to another telemetry system, is also adaptable to the radio tracking and telemetry of Minitrack signals from the satellite. These systems, both of which use phase comparison techniques and both of which are appropriate for construction and use by volunteer groups, will be described in later issues of the *Bulletin*.

General headquarters for the Moonbeam program are at the Naval Research Laboratory. The Jet Propulsion Laboratory is assisting and is maintaining a Moonbeam information office for the western United States. These offices are supplying technical information and consulting assistance to interested groups with regard to equipping, establishing, and operating stations in the Moonbeam volunteer radio network.

The American Radio Relay League (ARRL) has a position of active support in the Moonbeam program. Design, technical, and operational information concerning Minitrack Mark II, Microlock, and telemetry systems, as well as information on the Russian satellite radio system, is being provided to radio amateurs through *QST*, the journal of the ARRL.

The 20 and 40 mc frequencies used in the first Russian satellite were subject to much greater ionospheric effects than will be the 108 mc signal chosen for the US satellite. These properties make the 108 mc signal more valuable for precision tracking and the scientific experiments based upon it. The 20 and 40 megacycle signals are more useful for obtaining ionospheric data. At the September 30–October 5 CSAGI Conference on Rockets and Satellites, the United Kingdom delegation proposed a method whereby the vertical variation in the ionosphere above the F2 maximum might be deduced from volunteer radio observations of the USSR satellite. Similar plans for obtaining ionospheric information were already underway within the USSR.

Photographic Tracking

The fourth type of volunteer participation, photography of satellite passages against the background starfield, is a very recent development and has not yet been organized into a formal program. However, the USNC-IGY Technical Panel on the Earth Satellite Program has endorsed the efforts of the Society of Photographic Scientists and Engineers (SPSE) to organize its several local sections in the US for the purpose of obtaining photographs meeting these specifications: Negatives are to be 4″ x 5″, the minimum plate size to provide the requisite reading accuracy; they are to show the track of the satellite orbit against a fixed starfield background; and the trace of the satellite orbit is to contain a marker blank, or gap in the trace line, whose leading edge is timed to an accuracy of 0.1 seconds. The photograph is to be taken with a tripod-mounted camera located at a US Coast and Geodetic Survey Triangulation Station Marker (of which there are more than 100,000 in the US).

SPSE recommends that the timing blank be produced by placement of a dark slide over the camera lens, or by rapping the camera lens to displace the track, in coincidence with the timing signal from Radio Station WWV. More sophisticated means of timing, involving magnetic tape records or electro-mechanical devices, will undoubtedly be used in many cases, but opportunities for securing satellite traces with manually timed interruptions are not being overlooked.

Experience of SPSE has indicated that the brighter of the USSR satellite bodies (1957 α1, the rocket shell) can be photographed at f/4.5 with films having an exposure index of ASA 200, when developed in D-19 for 5.5 minutes at 68°F. (Fig. 1 describes the tentative system of notation for artificial earth satellites suggested by Fred L. Whipple of the Smithsonian Astrophysical Observatory.)

SPSE reports that the fainter trace of USSR satellite 1957 α2 (the sphere itself) can be photographed at f/2.8 using a new superfast emulsion having an exposure index of ASA 1600. There is, however, some question as to the feasibility of obtaining technically acceptable negatives of satellite α2. In spite of the technical difficulties and equipment requirements for satellite photography, it is anticipated that an active and productive program is in prospect.

Plans for the US satellite call for an orbit observable from within a wide latitudinal belt, from 40°N to 40°S. Volunteer groups too far north or south to observe the first US satellite can, nevertheless, observe the USSR satellite, which was launched in an orbit inclined 65° to the equatorial plane and which is therefore observable from all the populated regions of the earth. Both the US and the USSR have announced their intentions to launch several satellites during the IGY.

HARVARD COLLEGE OBSERVATORY
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Satellite 1957α — Since artificial earth satellites are short-lived astronomical bodies they should, presumably, be handled observationally and orbitally as are comets. As a tentative system of notation, pending IAU agreement, we shall identify each one by the year of its launching, followed by a letter of the Greek alphabet, to indicate successive order of launching. When more than one object is observable from one launching, a number shall follow the Greek letter in inverse sequence of brightness; the brightest component shall be α1, the next brightest α2, etc.

From press and radio accounts, Satellite 1957α was launched by the USSR during the night of October 3-4. Observations of only two components have been reported to the Astrophysical Observatory of the Smithsonian Institution. All estimates of brightness for α1 (both visual and photographic) give the second magnitude. Estimates of α2 range from the 4th to the 6th magnitude. From USSR reports of the satellite's dimensions, α2 is probably the radio satellite and α1 is the last rocket stage.

FIG. 1.

Moonwatch Observing Methods

The National Academy of Sciences, assigned to the Smithsonian Astrophysical Observatory responsibility for the initiation of an optical tracking program for US earth satellites. A vital part of this program can be carried out only by a corps of qualified visual observers who, in organized groups, man selected strategic observing stations. The following information was adapted from the Bulletin for Visual Observers of Satellites, *which is prepared by the Smithsonian Astrophysical Observatory and printed by* Sky and Telescope.

The Observing Team

The basic principle of Moonwatch station organization is that there be a team of observers, each of whom maintains continuous watch (during the observing interval) of a specified sky area on the celestial meridian. These areas overlap so that the satellite cannot cross this "meridional fence" without being detected. This is the recommended arrangement to be used at least during the first observations for the acquisition of the satellite.

The Essential Data

In all problems of orbit calculation and analysis, the computing center will use the right ascension and declination of the satellite in the sky, and the time it occupied that position. These are the essential data of a successful Moonwatch observation.

For computing purposes, any one of several observing techniques might be used, and the satellite could be observed in almost any part of the sky. The results are reported to the computing center in whichever of the several systems of co-ordinates seems most convenient. The basic requirement is that the position be given to an accuracy of one degree of arc and the time to an accuracy of one second.

There are, however, certain practical advantages in narrowing the choice of methods. For instance, the desirability of establishing a meridional fence as the basis of any Moonwatch observing routine is well established. Since the US satellite's motion will be predominantly from west to east, when it does pass within range of a station it will almost certainly have to cross the meridian. It will, in fact, always reach its greatest height above the horizon and be in the best position for observation not far from the meridian. In the absence of more specific information about the satellite's orbit, the meridian is obviously the most profitable part of the sky to watch for the US satellite.

The time and position reported to the computing center, then, will always be determined at or near meridian passage. Next, how can the observations best be made?

Two Observing Techniques

Two basic methods used by astronomers to determine the position of a celestial body are the fundamental and the differential.

The fundamental method involves direct measurement by means of instruments such as a meridian circle. For example, as a bright star crosses the meridian, its declination can be found by measuring its altitude, while its right ascension is equal to the sidereal time of the meridian passage.

The differential method involves the measurement of differences in position, either on a photographic plate or with a telescope micrometer, between the object whose position is desired and nearby stars whose places are already known. Such techniques are used at observatories to find the position of comets and asteroids, and they will be used to determine the position of the satellite in the precision photographic tracking program.

Either of these two basic methods of the astronomer can be adapted to the needs of Moonwatch. The first method can be used if a marker is provided, either a mast or a

reticle, that accurately defines the meridian in the field of the observer's telescope (see Fig. 2). All the observer must do is give the time signal and note the satellite's position, as it blinks out behind the marker, in fractions of the field above or below the center.

Since the angular size of the field and the position of the telescope on the meridian will be known, the meridian altitude can be computed easily as soon as the satellite has left the field. It will be necessary to state whether the satellite passage was north or south of the zenith. The computing center, knowing the latitude and longitude of the station, can readily convert the meridian altitude of the observations into declination and the time into right ascension—the data that will be used in the electronic computer.

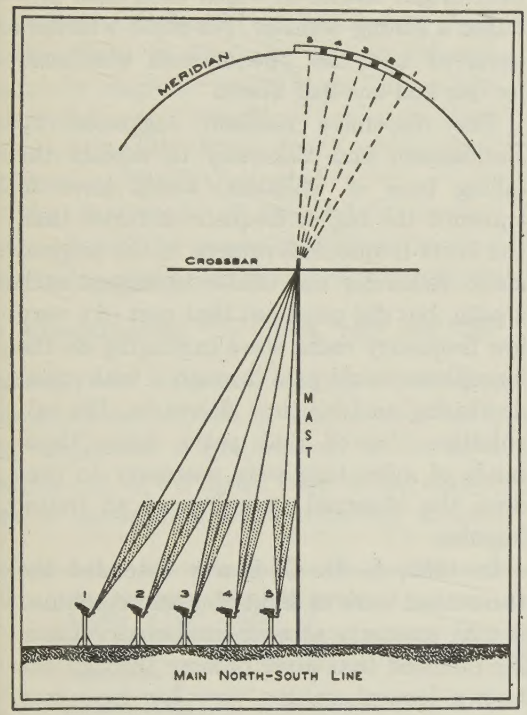

FIG. 2. IGY Moonwatch Station: main north-south line. Observing instruments are oriented relative to the junction of mast and crossbar. The upper part of the diagram shows the 12° fields of view of the instruments on the celestial meridian. The fields overlap about 1½° to prevent the satellite from crossing the "meridional fence" unobserved.

The second method, in its simplest form, makes use of star charts alone, without the aid of a meridian marker. The stars provide a background against which the position of the satellite can be determined at any moment during its passage across the field of the telescope. The accuracy of the observation may be considerably increased if the position is timed when the satellite passes close to a bright star or a prominent group of stars.

Therefore, it will be perfectly acceptable if a team of experienced observers decides to adopt the second method and eliminates the meridian marker entirely. This will obviate the work of erecting a mast or of inserting reticles in telescopes. The telescope field is unobstructed, with a consequent reduction in observer fatigue. Further details for those intending to participate in the program can be found in the *Bulletin for Volunteer Visual Observers* or by writing to The Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge 38, Mass.

Whistlers and Related Phenomena

Whistlers are naturally occurring audio frequency radio waves which, received on an antenna, amplified, and fed to a transducer for conversion into sound, can be heard as long descending whistles. They were first discovered in Austria in 1886, and in 1893 a report of some six years of investigation on them was published. Although this was overlooked until recently, the German scientist Barkhausen rediscovered them

while eavesdropping on Allied military telephone conversations during the first World War. Using a sensitive audio amplifier connected to a pair of separated ground rods, he recognized the phenomenon as a new one and called the descending tones "whistlers."

The observation of whistlers and related phenomena has great importance because of their potential usefulness in providing information about the very high atmosphere—the region above the level accessible to observation by ionospheric sounders. Whistler observations expanded in scope only when theory was developed to explain the origin and propagation of the signals themselves. Added impetus was given to an observational program when theory suggested that a complete experimental understanding of the nature of whistlers would provide new insight into conditions in the very high atmosphere. Observations had fortunately reached a stage ready for development into a broad synoptic program on the eve of the International Geophysical Year.

Development of Whistler Theory

The first advance in understanding whistlers came when Barkhausen and Eckersley independently suggested that the signals might arise from the propagation of sferics over long, dispersive paths. Sferics are transient radio waves arising from naturally occurring electric discharges in the earth's atmosphere. The most intense atmospheric discharges are lightning; nevertheless, all lightning strokes do not produce sferics. Through the work of A. G. Jean of the Central Radio Propagation Laboratory, National Bureau of Standards, at Boulder, Colorado, in cooperation with Stanford University, it is now known that there is a characteristic sferic wave form associated with whistlers and that it has a relatively low frequency of occurrence. Most whistlers are produced by sferics that are relatively rich in energy below 10 kc/sec. However, sferics with the usual energy spectrum peaking in the 10–20 kc region can produce whistlers if their total energy is sufficiently large.

Until recently there was still some doubt that lightning flashes generated whistlers, but this has now been resolved. On May 27 of this year, M. G. Morgan of Dartmouth College successfully observed a local storm with bright flashes in which each flash produced a strong whistler. No other whistlers occurred and the phenomenon continued for one and one-half hours.

The dispersive medium suggested by Barkhausen and Eckersley to explain the falling tone of whistlers, would have to transmit the higher frequencies faster than the lower frequencies present in the original sferic. Eckersley was unable to suggest such a path, but did point out that part of a very low frequency radio wave impinging on the ionosphere would pass through it with speed decreasing as frequency decreases. His calculations showed that paths many thousands of miles long were necessary to produce the observed spreading of an initial impulse.

In 1953, L. R. O. Storey extended the theoretical work of Eckersley and combined it with extensive experimental observations. He deduced that after passing through the known ionosphere, the very low frequency energy from a lightning flash is guided far above the earth and down again to the symmetrical point in the opposite hemisphere by the lines of flux of the earth's magnetic field. For the wave to be channeled along this path with the observed delays, an average electron density of about 400 electrons per cubic centimeter is required. Tentative theoretical explanations of the zodiacal light observed along the ecliptic constituted the only other basis for expecting such high electron concentrations at great distances from the earth.

Storey's deduction of the path of whistlers was given support in several spaced-station tests. A year-long correlation of whistlers at Stanford and Seattle confirmed the predicted localization of whistler energy. Sferics observed on the USS. *Atka* in the

southern hemisphere in 1954 were found to produce whistlers at Stanford. As expected, a three-year test at Achimoto (West Africa), on the geomagnetic equator, showed no whistlers.

In 1955, G. McK. Allcock of the New Zealand Dominion Physical Laboratory and H. W. Curtis of Dartmouth College conducted a coordinated experiment in New Zealand and at Unalaska at the opposite ends of a magnetic line of force. The results confirmed the occurrence of coincident whistlers having the expected relationships at the two ends of the path.

The importance of the whistler experiments is readily appreciated from the fact that the propagation time given by theory is approximately $\frac{D}{\sqrt{f}}$ for a very low frequency radio wave of frequency f traveling along the earth's field in the ionosphere. D, the dispersion, is proportional to the path length and to the mean value of the square root of the ratio of electron density to field strength. Typically, 5% of the total dispersion would result from the effect of the known ionosphere. Thus, models of the outer ionosphere can be inferred from experiment.

It has been found that whistlers are not observed at very high geomagnetic latitudes (the minimum strength of the earth's field is too low) or at very low ones (flux lines are too short to develop whistlers). Whistlers sometimes occur in trains of successive echoes. This is well illustrated in Fig. 3, which presents data from an Unalaska-New Zealand experiment. Note that here the dispersion increases by simple multiples, as expected.

IGY Whistler-Study Program

On the basis of the evidence sketched briefly above, the US-IGY whistler observational program was formulated. It includes two chains of stations for the observation of whistlers, and sometimes sferics, at frequencies up to 30 kc/sec. An eastern

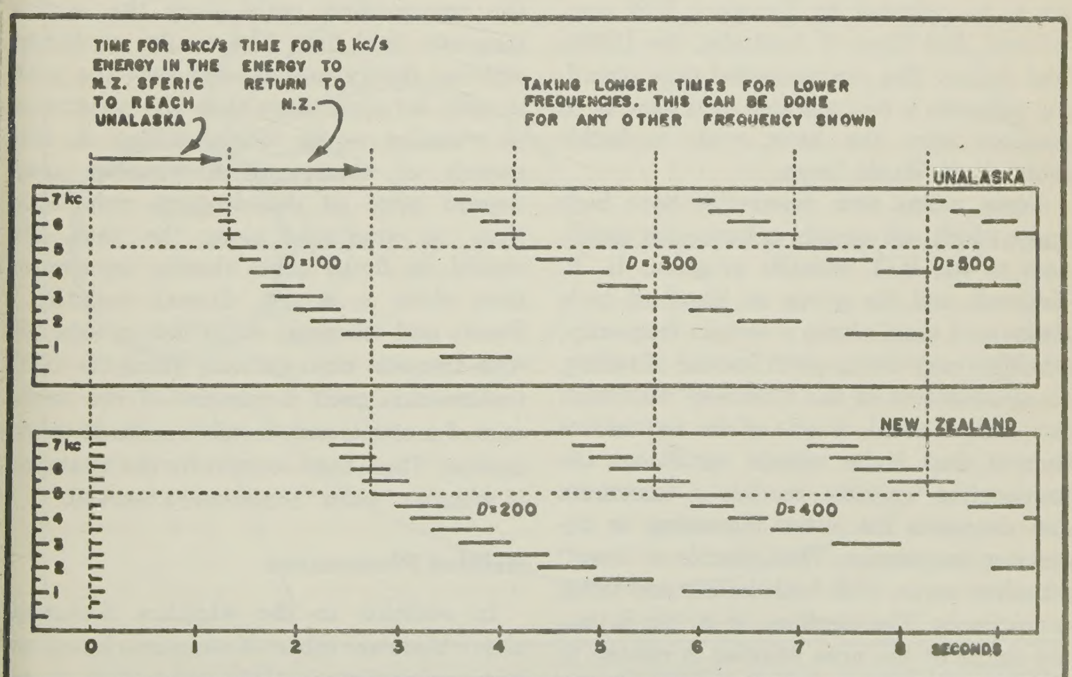

FIG. 3. Frequency and time of occurrence of whistler echoes between New Zealand and Unalaska, Alaska. Note that the dispersion, D, increases with increase in time.
After Morgan, Annals of the IGY, v. 3, p. 315, 1957.

network under the supervision of M. G. Morgan of Dartmouth College includes stations at Thule, Greenland; Frobisher Bay, NWT; Knob Lake and Mont Joli, Quebec; Hanover, New Hampshire; Battle Creek, Michigan; Washington, D. C.; Bermuda; Gainesville, Florida; Huancayo, Peru; Cape Horn, Argentina (with the cooperation of Argentina); Port Lockroy, Antarctica (with the cooperation of the United Kingdom); and Ellsworth Station, Antarctica. A Danish station at Godhavn in Greenland is also coordinating its observations in this program.

A western network under the supervision of Robert A. Helliwell of Stanford University includes the following stations: College, Kotzebue, Unalaska, and Anchorage, Alaska; Seattle, Washington; Boulder, Colorado; Stanford, California; Wellington and Dunedin, N. Z. (with the cooperation of New Zealand); and Macquarie Island (with the cooperation of Australia).

Canadian stations are situated at Saskatoon, Ottawa, and Halifax. Other stations are to be operated by European IGY committees, and those of Australia, the USSR, and Japan. The recommended tape recording program is two minutes each hour at 35 minutes after the hour, with a double schedule on World Days.

Some recent new discoveries have been made which will greatly enhance the usefulness of the IGY whistler program. R. A. Helliwell and his group at Stanford have discovered that, above a certain frequency, whistlers may rise in pitch instead of falling. Re-examination of the Eckersley dispersion law and removal of one of its restrictions showed that under certain conditions the propagation velocity reaches a maximum and decreases for either increasing or decreasing frequencies. Thus, double or "nose" whistlers occur, with both falling and rising components. The significance of this is that the shape of the nose whistler is related to the intensity of the earth's field along the whistler path and gives information on the distribution of ionization as well. From this it is theoretically possible to place limits on the location of the path of propagation and, in addition, to obtain the distribution of ionization along the whistler path. With classical whistlers it would be possible only to determine the integrated value of the ionization over an assumed path of propagation. From nose whistler data the electron density is estimated to vary from several thousand per cm^3 at one or two earth radii to a few hundred at four or five radii.

As whistler phenomena have been examined more closely, other interesting phenomena have also come to light. Storey has noted that the detection of certain minor deviations from the predicted dispersion law would indicate the presence of hydrogen ions along the path. Work by K. Maeda, in Japan, has shown that the whistler path may depart markedly from the magnetic field-line path.

In January of this year, whistler mode echoes transmitted from NSS at Annapolis on 15.5 kc/sec were detected by the Stanford group at Cape Horn. Fig. 4 illustrates the transmission path along the earth's magnetic field line. The results confirmed whistler theory and showed that the path is open far more often than the occurrence of whistlers would indicate. That is, frequency of occurrence of whistlers may depend more on thunderstorm conditions than on conditions along the path. (It should be noted that whistler occurrence does show a strong diurnal variation.) Severe and relatively rapid fading together with frequent echo splitting along the NSS transmission path demonstrated the existence of multiple and unstable paths of propagation. These may account for the existence of whistler "pairs" sometimes observed.

Related Phenomena

In addition to the whistlers discussed above there are other vlf emissions heard on whistler apparatus. The simplest of these are the tweeks which last less than one-tenth of a second and are probably the re-

sult of transmission of sferic energy by successive reflection between the E layer and the earth over paths of different skip length. Other emissions such as hiss, constant tones, and the so-called dawn chorus of overlapping rising tones generally confined to the mid-audio range are not well understood. H. E. Dinger of the Naval Research Laboratory has studied periodic effects in the dawn chorus.

Recently a theory has been advanced by Roger Gallet and R. A. Helliwell to account for the unusual vlf emissions. It is based on selective amplification of noise energy already present in the medium. Energy for the amplification is provided by streams of ionized particles which come from the sun and travel along the lines of the earth's magnetic field. These streams are assumed to penetrate the ambient ionization of the exosphere with relatively little interaction. The mechanism of amplification is very much like that of traveling wave tubes. The velocity of the incoming particles must match that of electromagnetic waves in the medium to accomplish the transfer of energy from particles to waves which are then propagated to the earth. This theory is compatible with the suggestion that the exosphere may be "fibrous" as suggested by the NSS experiment. Even the dawn chorus may be explained by the theory if it is assumed that the ionized stream is bunched upon arrival.

M. G. Morgan has sought a correlation between vlf emissions and aurora since both are strongly correlated with geomagnetic disturbance; he reports that such a correlation is evident in every notable display of

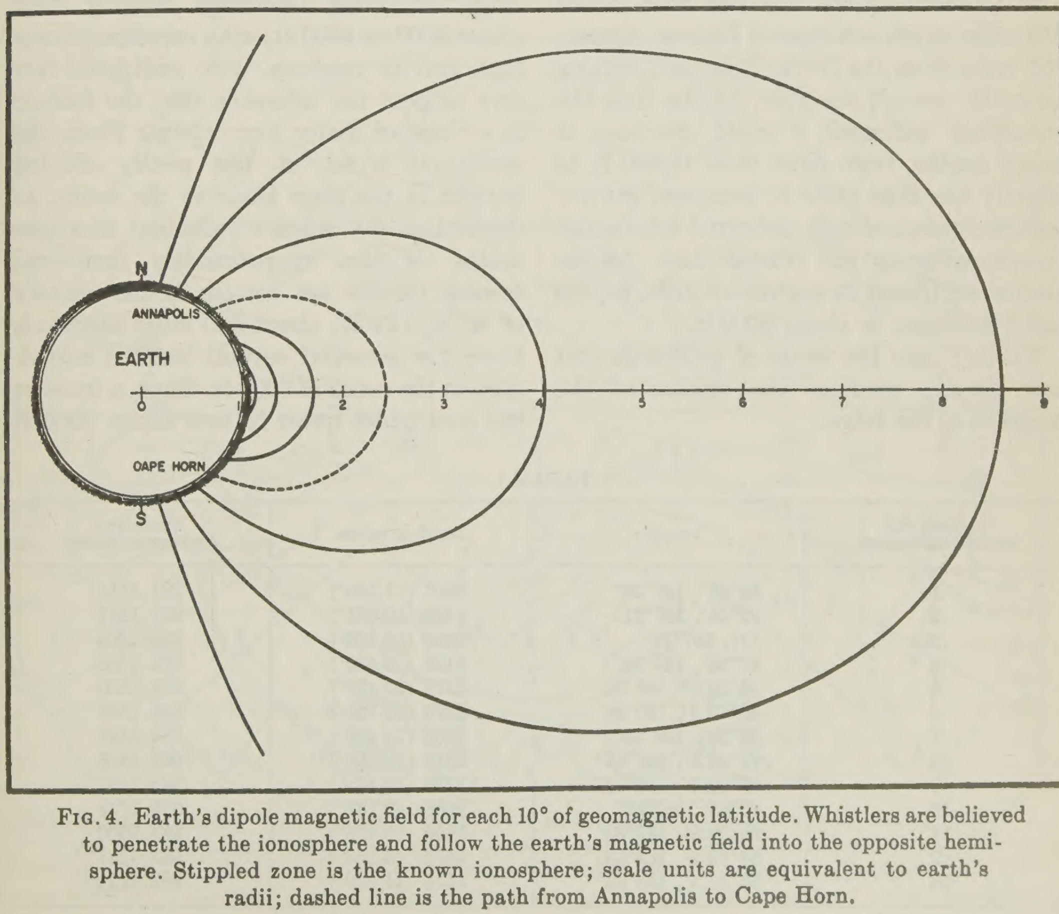

Fig. 4. Earth's dipole magnetic field for each 10° of geomagnetic latitude. Whistlers are believed to penetrate the ionosphere and follow the earth's magnetic field into the opposite hemisphere. Stippled zone is the known ionosphere; scale units are equivalent to earth's radii; dashed line is the path from Annapolis to Cape Horn.

flaming auroral rays. This appears to be consistent with the Gallet-Helliwell theory of vlf emissions.

An important part of the IGY whistler program will be the study of vlf emissions for the purpose of testing the traveling wave theory or developing new theories of their origin. These phenomena may provide a new way to measure the densities and velocities of solar streams. Plainly, the IGY whistler and vlf emission program promises to be a fruitful one in providing new knowledge of these emissions and of the atmosphere through which they travel.

Arctic Ocean Submarine Ridges

On August 12, 1957, geophysicists on IGY Drifting Station A, in the Arctic Ocean, reported that the ice floe on which the station is established had floated over a submarine ridge, or mountain range, rising more than 5000 feet above the ocean floor.

The feature was discovered in the course of a series of daily seismic depth soundings combined with gravimeter measurements. The two-mile-square floe was then about 850 miles north and west of Barrow, Alaska, 550 miles from the North Pole, and drifting generally toward the Pole. At the time the soundings indicated a rapid decrease in ocean depths, from more than 10,000 ft to slightly less than 5000 ft, increased gravity values correspondingly indicated substantial compensation in the crustal mass. As the station continued its northward drift, depths again increased to about 8000 ft.

Table 1 lists the series of soundings and raw gravity readings that indicated the presence of the ridge.

Although it was not possible to determine the length and width of the ridge on the basis of a single track, the fact that the gravity anomaly was first detected a full 60 miles from the point where the ridge was found suggests a major feature rather than an isolated one. For several days following the discovery, the station drifted westward, roughly parallel to the apparent trend of the ridge, obtaining soundings ranging from about 5000 to 5500 ft, with correspondingly high gravity readings. Two additional factors support the inference that the feature is a ridge of major proportions: First, the structural trend of the gently sloping bottom in the deep basin to the south, as determined by seismic reflection measurements, is also approximately east-west; second, for the sea bottom in the vicinity of 86°N, 125°W, about 300 miles eastward, there are recorded several isolated soundings on the order of 6000 ft. Thus, a more or less continuous linear feature about 5000 ft

TABLE 1

Hydrographic observation number	Location	Depth in meters	Uncorrected gravimeter reading
1	82°54′, 167°28′	3507 (11,506′)	983.1514
2	82°54′, 167°31′	3152 (10,341′)	983.1661
3	(?), 167°27′	3199 (10,495′)	983.1605
4	83°08′, 167°24′	3185 (10,450′)	983.1580
5	83°13.5′, 166°24,	3178 (10,427′)	983.1590
6	83°19.5′, 166°20′	3270 (10,728′)	983.1557
7	83°24′, 166°18	3186 (10,453′)	983.1557
8	83°36.5′, 166°15′	3156 (10,354′)	983.1548
9	83°39.5′, 166°12′	3106 (10,172′)	983.1547
10	83°48′, 167°01′	2968 (9,737′)	983.1739
11	83°52.5′, 167°50′	1656 (5,433′)	983.2060
12	83°52.1′, 168°38′	1571 (5,154′)	983.2121
13	83°51.5′, 168°43′	1515 (4,970′)	983.2118

high and trending generally east-west is indicated.

If the feature actually forms a continuous barrier across the Arctic, hydrographic studies should eventually detect a difference in the water masses on both sides. They will also provide a reliable estimate of the minimum depth to which the ridge forms such a barrier to the deep circulation. Temperature measurements made from Station A to depths of 10,500 ft south of the ridge and 6000 ft north of it indicate no difference in water mass down to the 6000-ft level. This means that the ridge does not form a continuous barrier above a depth of 6000 feet as the water mass on both sides of of it has evidently been equalized to that depth by movement through gaps in the ridge. Similar measurements made in the deeper water to the north will determine whether a continous barrier is formed by the lower portion of the ridge.

Although its topographic extent is uncertain, the new ridge appears to parallel the great Lomonosov ridge, which stretches from the northern coast of Ellesmere Island to the Soviet islands of Novosibirskiye Ostrova, dividing the Arctic Basin almost in two (see Fig. 5). The Lomonosov, discovered in 1948 by USSR scientists occupying similar drifting stations, is about 10,000 ft high. The deep soundings taken to the south of the position of the new ridge make it unlikely that it is a northward extension of the submarine peninsula known to trend north from the Chukchi Sea. (The Chukchi Sea reaches from the Bering Strait to the Arctic Ocean, between northwestern Alaska and Siberia.) There is a minor possibility, however, that the Chukchi Sea peninsula bears westward south of the region in which

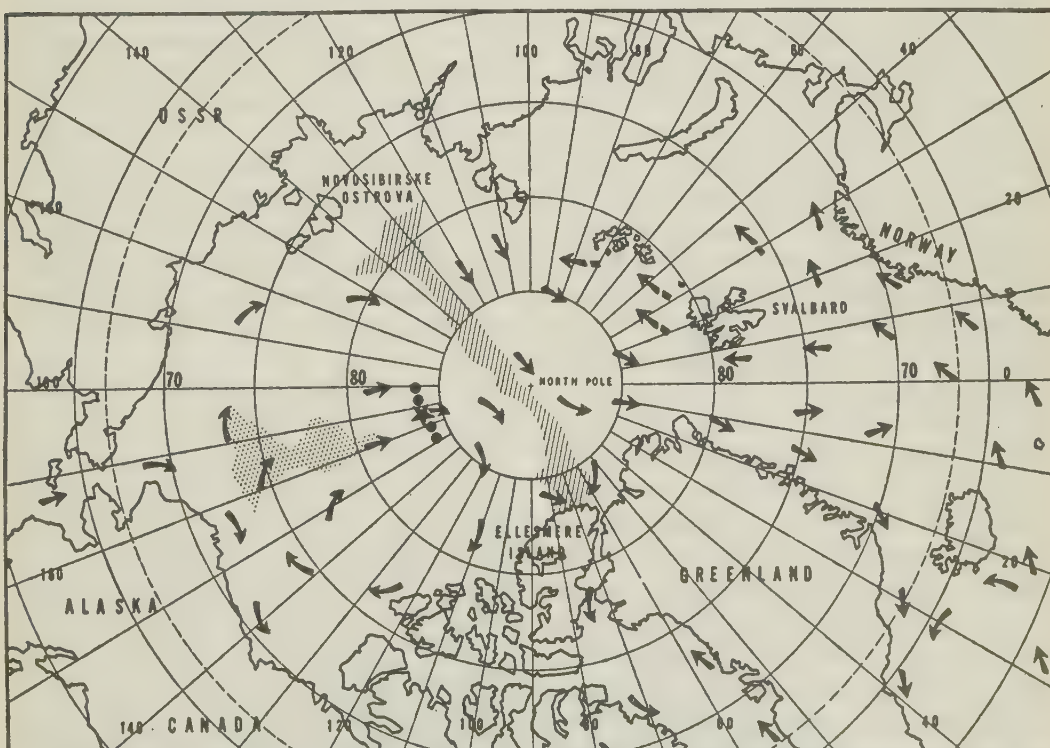

FIG. 5. Arctic Basin. Black star is IGY Drifting Station A at approximate position of newly discovered submarine ridge (black dots). Vertical pattern is Lomonosov submarine ridge; Stipple pattern is Chukchi submarine peninsula. Solid arrows are major known surface currents; broken arrows are major known subsurface currents.

the deep soundings were taken and then curves back to the northeast.

The team of scientists manning the station, then led by Maurice J. Davidson, are attached to the Lamont Geological Observatory of Columbia University. Their work is sponsored by the USNC-IGY and the US Air Force Cambridge Research Center.

Discovery of these submarine ridges and knowledge of their overall topographic dimensions and shapes is of great importance, particularly because of their strong influence on water movements. The overturn, mixing, and current flow of Arctic surface and subsurface waters must be known if we are to understand the mechanism of refertilization of the rich subarctic fisheries, the relationships between Arctic Ocean meteorology and oceanography, and the movement of the ice pack.

Most surface ocean currents are motivated both by winds and by differences in water density resulting from heating and cooling. Deep currents derive their energy primarily from density variations. Only in the Arctic Ocean does circulation occur to great depths with no significant aid from the winds. Although the winds are able to move the ice pack to some degree, it is believed that the ice exerts only a minor frictional effect on the water. Most of the Arctic Ocean circulation appears to result from level-for-level variations in density between the arctic waters and the waters of the Norwegian Sea, with which the major exchanges occur. Although current velocities beneath the ice may be weak, it has been shown that considerable movements of water mass are involved.

Bottom topography must, therefore, play an important role in the deep circulation of the Arctic Ocean, which, in turn, in the absence of the disturbing effects of direct contact between the wind and the water surface, must significantly influence circulation in the upper levels. The polar deep water is formed at depths of about 8000–9500 ft in the Norwegian Sea from which it flows into the Arctic Basin. Temperatures of −0.79° to − 0.91°C have been found at these depths near Svalbard, in the eastern part of the Basin.

In the Beaufort Sea, north of Alaska, however, bottom temperatures, at depths somewhat greater than 7000 ft, are as much as 0.50°C higher. To explain this differential, one investigator with the US Ski Jump project several years ago suggested the possible existence of a submarine ridge cutting the Basin in two. The later Soviet announcement of the discovery of the Lomonosov ridge confirmed this speculation.

Warmer Atlantic water flowing into the Arctic Basin sinks to intermediate levels in the Basin. It has been found north of the New Siberian Islands, near the "Pole of Inaccessibility" in the western part of the Basin, and at all Soviet stations near the geographic North Pole in a layer between depths of about 900 and 2350 feet. The cold north polar surface water originates in the Basin and flows out along the east coast of Greenland as the Greenland Current. Owing to the existence of the Lomonosov ridge, the Arctic Ocean appears to have two separate circulation systems: the system on the Pacific side flowing clockwise and the one on the Atlantic side flowing counterclockwise and involved in direct exchange and mixing with waters from outside the Basin.

An interesting effect of this dual system is that ice leaves the basin only from the Atlantic side, by way of the Greenland Current. Hence, the ice trapped in the more-or-less isolated system on the Pacific side is older and heavier than that on the Atlantic side. This phenomenon influences considerably attempts at ice forecasting for the Basin, and would probably greatly affect the overall pattern of ice wastage if the Arctic continues to grow warmer.

A complete understanding of the significance of submarine ridges in the Arctic in terms of their geological nature and origin, their effects on water mass differentials and circulation and, ultimately, on arctic and

subarctic marine life, as well as on the movement, accumulation, and ablation of the ice pack, will require considerably more data than are now available. By the end of the IGY, the cumulative efforts of US and USSR scientists on Arctic Ocean drifting stations may provide answers to these problems.

Oceanographic Island Observatory in Iceland

Some of the general objectives of the oceanography program were discussed in *IGY Bulletin No. 2, August 1957.* A worldwide study of sea level was included in the international IGY program in an effort to understand an observed cycle of mass deficiency between the northern and southern oceans depending on season. It has been observed from study of tide gauge records that the mean sea level in March is perhaps 20 cm lower than in September, for the Northern Hemisphere; the reverse is true in the Southern Hemisphere. In other words, sea level is lower in the spring.

Another observation gained from study of mean sea level is that there appears to be a mass loss in the northern hemisphere oceans between October and March. Walter Munk of Scripps Institution has estimated that the northern hemisphere oceans lose about 2×10^{19} grams of water while the southern hemisphere oceans only gain about 1×10^{19} grams. This mass difference corresponds to a sea level change of about 4 cm. There is so much uncertainty in this estimate, however, that the loss may be twice as much, or almost none at all.

The major objective of the IGY sea level program is, therefore, to obtain more reliable and accurate measurements for the values of mean sea level. Although there are about 500 tide gauges in operation throughout the world, there are many gaps, and few gauges are at islands or are located in the interior of water covered areas. About 200 to 250 new stations have been established for the IGY; the program is called Island Observatory Program because of the emphasis on island locations for the new stations, especially in the central oceanic areas. The southern hemisphere also was particularly lacking in tide gauges, and the continental coasts of this hemisphere are, therefore, the sites of many new stations.

One of the difficulties of computing mean sea level data from tide gauge records alone is the problem of distinguishing between mass changes and the volumetric changes. Accordingly, water samples are taken with simplified sampling bottles to depths of about 1000 feet. At the same time a bathythermograph is lowered to obtain a temperature profile. Using salinity measurements from the water samples combined with the temperature profiles, the densities can be computed and the apparent height of the water column reduced to a standard datum, allowing comparisons between oceanic areas of different temperature structures and salinities.

The location of many new tide-gauge stations at islands and coastal areas previously devoid of such instrumentation provides an opportunity for location of other instruments for a diversity of studies. Specially designed instruments have been installed at many locations to study the surface wave structure, from ordinary local wind waves with periods of a few seconds to waves of 15- to 20-minute periods caused by undersea earthquakes or perhaps generated by the great storms of the central oceanic areas. There is considerable transfer of momentum between atmosphere and oceans, as manifested by waves and surface currents, and recording microbarographs and microvariobarographs are in operation at many locations to provide atmospheric data along with the wave records in order to study the atmosphere-ocean coupling.

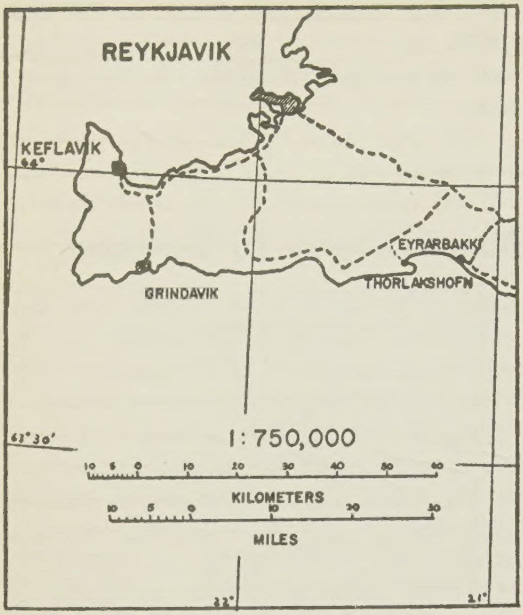

Fig. 6.

As an example of the newly established island observatories, Fig. 6 shows the location on Iceland of the tide gauge (US Coast and Geodetic type) at Grindavik and short- and long-period wave meters, thermograph, microbarograph, and microvariobarograph at Thorlakshofn. These instruments were installed by personnel from Lamont Geological Observatory with the assistance and cooperation of Icelandic scientists and authorities.

The location of the tide gauge at Grindavik presents some problems in analyzing the records owing to the nature of the harbor. Grindavik is a small fishing village; its harbor, called the *Hop*, is artificial and is connected to the sea by a narrow channel. The average tidal range inside the *Hop* is approximately 12 ft, and during the rising and falling tides swift currents flow through the narrow channel. It is estimated that there will be a phase lag between the sea and harbor tides of perhaps 10 to 15 minuntes and that harbor seiches, when they occur, will be of the order of 5 minutes in period.

Thorlakshofn is also a small fishing village, situated on a promontory which forms the southwestern shore of a large crescent-shaped embayment called Thorlakshafnarvik. Vessels as large as 5000 tons can tie up to the pier. The area is wide open to sea swell from the southeast to the southwest, and during stormy winter months waves often break over the concrete pier, which stands 10 ft above mean water level.

The short-period wave meter is installed at a depth of 30 ft, about 1000 ft from the end of the pier, while the long-period wave meter is installed at a closer location. Originally, both wave meters were installed 300 meters from the end of the pier at a depth of 30 ft. Subsequent failure of the long-period wave meter caused its removal and its later installation at a point closer to the end of the pier. Armored sea cable from the wave meters comes ashore at the seaward end of the pier, where it is connected to a telephone junction box; a lead-sheathed telephone cable connects the junction box to the shore recorders, at a distance of about 1500 feet. This type of installation was made necessary because wave action would have rapidly worn away the armor of the cable against the shingle and cobbles of the beach if the cable crossed the shore line at any other point.

At Thorlakshofn, the shore installation is located in a room adjoining the office of the local fishing company and consists of the recorders for both meters, a microbarograph, a thermograph, and will also contain the microvariobarograph. The short-period wave recorder, which has a flat response to waves of periods between 4 and 20 seconds, is pre-set to have full-scale readings corresponding to either ± 2 feet or ± 10 feet of water. The operator selects the appropriate sensitivity scale in accordance with local sea conditions.

The long-period wave meter has a maximum response to a period of 1000 seconds; it can resolve wave signals with amplitudes as low as a few millimeters of water. Temperature is also recorded on the chart in order to provide conveniently for the necessary corrections. A louvered outdoor shelter

houses the thermograph. Both wave meters and the microvariobarograph record on 35 mm film using a microfilm recorder that was adapted for this purpose.

Fig. 7 shows the kind of records obtained from the special instrumentation at the Island Observatories. The records were obtained at Iceland during tests of the installation; the three instruments were not operating concurrently. The upper record shows the short period waves ranging from ordinary wind waves with periods of a few seconds to wave trains of 15- to 20-second periods. The latter probably originated from a severe storm at some distance; they fall into the classification of "sea swell."

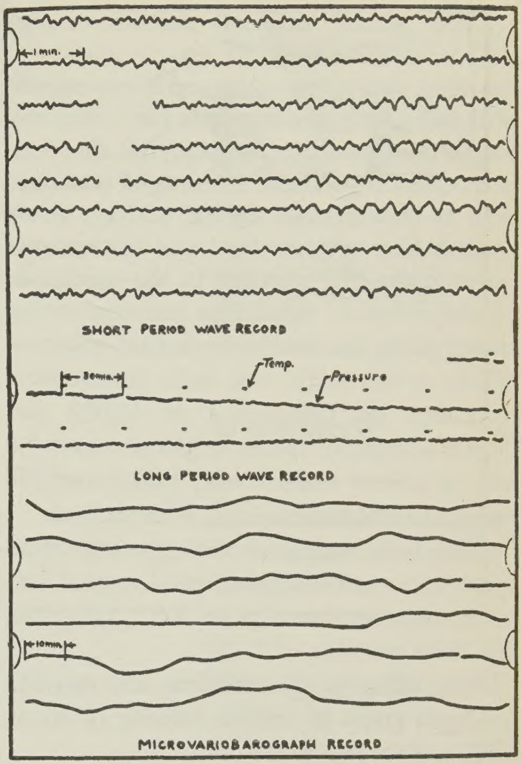

FIG. 7.

The middle record shows a sample from the long-period recorder, where short-period waves and the very long tide waves are filtered out. Temperature is recorded every half hour. This particular record shows the arrival of some small long-period wave trains; the gradual decrease in the record in the middle section is probably caused by that part of the tide which has not been filtered out.

Examples of records from the microvariobarograph, which records the rate of change of the barometric pressure, are shown at the bottom of Fig. 7. This instrument indicates the passage of cold fronts and pressure changes associated with other meteorological phenomena.

The installation was made possible through the participation and cooperation of the Icelandic Harbor Administration (Vita-Og Hafnamalastjrinn), under the direction of Mr. Petur Sigurdson, and the fishing industry at Thorlakshofn (Meitilluim h.f.), Mr. Benedict Thorareuson, General Manager. The area for the sea installation was surveyed by the Icelandic Survey Vessel *Tyr* under the command of Mr. Gunnar Bergsteinson, and the wave meter assemblies were installed in the sea by the fishing vessel *M. B. Klengur*. Mr. Arni Benedictson is in charge of this cooperative station at Thorlakshofn, Iceland.

Second Soviet Satellite

The USSR launched its second satellite on November 3, 1957. The following descriptive text was issued on that date by Tass:

"In conformity with the International Geophysical Year program for studying the upper layers of the atmosphere as well as the physical processes and conditions of life in cosmic space, the second artificial earth satellite was launched in the Soviet Union on 3rd November.

"The second artificial satellite developed in the U.S.S.R. represents the last stage of the carrier rocket housing containers with scientific instruments.

"The second artificial satellite carries instruments for studying solar radiation in the short wave ultra violet and X-ray regions of the spectrum, instruments for cosmic ray studies, instruments for studying the temperature and pressure, an airtight container with an experimental animal (a dog), an air conditioning system, food and instruments for studying life processes in the conditions of cosmic space, measuring instruments for transmitting the results of scientific measurements to the earth, two radio transmitters operating on frequencies of 40,002 and 20,005 kilocycles (wave length of about 7.5 and 15 metres respectively) (292.5 and 585 inches) and the necessary power sources.

"The total weight of the apparatus mentioned above, the experimental animal and power sources amounts to 508.3 kilograms (1,120.29 pounds).

"According to observations the satellite has been given an orbital velocity of about 8,000 meters per second.

"According to calculations which are being verified at present by direct observations, the maximum distance of the satellite from the earth's surface exceeds 1,500 kilometers.

"The time of one complete circuit is about one hour, 42 minutes. The angle of the incline of the orbit to the plane of the equator is approximately 65 degrees.

"According to information received from the satellite, the scientific instruments and control of the life processes in the animal are proceeding normally.

"On 3rd November the second artificial satellite passed over Moscow at 7:20 A.M. and will appear again at 9:05 A.M.

"The signals of the satellite's radio transmitters on the 20,005 kilocycles are given in the form of telegraph beats lasting about 0.3 seconds with a pause of an equal duration. The 40,002 kilocycles transmitter emits continually."

Observations: Radio signals from the satellite were picked up early on November 3 by the RCA station at Riverhead, L. I., by the Naval Research Laboratory in Washington, by other government and private laboratories and by amateur operators throughout the country. Moonwatch observers and amateur astronomers in the Eastern states observed and photographed the satellite. Both visual observations and photographs showed a fluctuation in intensity of the light from the satellite, indicating that it was either tumbling or yawing.

Radio signals from the satellite ceased on November 10. On November 13, Pravda published a statement saying, "The program of scientific research connected with taking measurements in the second artificial satellite was planned for seven 24-hour periods. This program has now been completed. The radio transmitters of the satellite, as well as the radio telemetrical instruments on board the satellite have finished their work. Further observations of the second artificial earth satellite, for the purpose of exploring the properties of the upper layers of the atmosphere and forecasting its movements, are being made through optical means and radar."

The *Antarctic Program of the US National Committee for the International Geophysical Year, 1957–1958,* 58 pp., illustrated, is available from the National Academy of Sciences, National Research Council, 2101 Constitution Ave., N. W., Washington 25, D. C. (Publication 553). Price $1.00.

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